6 LEVEL II

Research and Development Technical Report

DELNV—76-0261-F

LOW VOLTAGE IGNITION SEALED BEAM XENON LAMP

ITT Electron Tube Division
3100 Charlotte Avenue
Easton, Pennsylvania 18042

1 November 1979

Final Report for the Period 1 October 1976 to 1 October 1979

DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited

Prepared for

NIGHT VISION LABORATORY
US ARMY ELECTRONICS COMMAND
FORT BELVOIR, VIRGINIA 22060

NOTICES

Disclaimers

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 19 18 DELNV-76-0261-F	2. GOVT ACCESSION NO. AD-A084 061	3. RECIPIENT'S CATALOG NUMBER rept.
4. TITLE (and Subtitle) 6 LOW VOLTAGE IGNITION SEALED BEAM XENON LAMP.	9	5. TYPE OF REPORT & PERIOD COVERED Final 1 October 1976 to 1 October 1979
	14	6. PERFORMING ORG. REPORT NUMBER ITT-1056.15
7. AUTHOR(s) 10 H. C. Grunwald		8. CONTRACT OR GRANT NUMBER(s) 15 DAAK70-76-C-0261 new
9. PERFORMING ORGANIZATION NAME AND ADDRESS ITT Electron Tube Division 3100 Charlotte Avenue Easton, Pennsylvania 18042		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 17 Task 1S763719DK70-03
11. CONTROLLING OFFICE NAME AND ADDRESS Night Vision Laboratory DELNV U. S. Army Electronics Command Fort Belvoir, Virginia 22060	11	12. REPORT DATE 1 November 1979 13. NUMBER OF PAGES 36
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 43		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Xenon
Sealed Beam
Low Voltage
High Pressure Lamp

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The task was to modify an existing 1.0 Kilowatt sealed beam lamp from the standard high voltage pulse starting to a low voltage mechanical starting arrangement.

Problems in the lamp development were met and solved. The program was not successful because of problems encountered

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

189720

with the associated circuitry which was developed elsewhere.

It was also concluded that the lamp design was marginal. Suggestions for a different approach to the problem are given.

LOW VOLTAGE IGNITION

SEALED BEAM XENON LAMP

FINAL TECHNICAL REPORT

Contract No. DAAK70-76-C-0261

ITT ELECTRON TUBE DIVISION
3100 Charlotte Avenue
Easton, Pennsylvania 18042

LOW VOLTAGE IGNITION

SEALED BEAM XENON LAMP

FINAL TECHNICAL REPORT

TABLE OF CONTENTS

1.0 SUMMARY

A development program has been conducted to modify an existing design of a metal ceramic sealed beam xenon arc lamp, which required a high frequency, high voltage ignition pulse to incorporate a low voltage ignition mechanism, internal to the xenon lamp. The program called for ITT to perform the necessary design, fabrication and test to develop the low voltage sealed beam lamp and to deliver three operating samples. ITT originally planned to fabricate a total of ten lamps to finalize the design and provide the three operating samples. Unexpected serious problems necessitated the modification of the milestone plan, doubled the quantity of lamps which were actually built and resulted in required extension of the delivery schedule.

The contract was a CPFF type of technical development program. Program extension was a direct consequence of serious unanticipated problems and resulted in a substantial cost overrun of the program, which ITT supported on its own funds.

The original plan of this program called for ITT to design a low voltage start mechanism which would be incorporated into the sealed beam lamp. The mechanism basically consisted of a small metal probe or stinger coaxially mounted within the anode structure, which would be activated by a magnetic circuit causing the probe to momentarily contact the cathode, then retract, permitting the low level DC voltage to initiate an arc. The major problem encountered in this program involved the stinger welding to the anode causing a permanent

short circuit. This problem was eventually traced to malfunction in the GFE electronic circuitry which controlled the timing of the magnetic activation circuits. After resolution of the circuit problem, the mechanical start mechanism performed the low voltage start requirement adequately and reliably.

Key components in the sealed beam xenon lamp include the very small self-contained reflector and the relatively large sapphire window. A large portion of the program involved design and manufacturing techniques aimed at reducing the cost and insuring the reliability of these components. ITT developed pilot facilities to fabricate the electrodes and believes that the electrode can be made in high volume at relatively low cost. The effort involving the sapphire window was less successful and serious questions concerning the reliability and production cost of this component remain.

Three engineering model lamps were fabricated, tested and delivered for evaluation to the Night Vision Laboratories.

ITT believes that there are serious questions regarding the reliability and cost of the sealed beam lamp design in its present configuration. The present configuration incorporates all of the key components of the active searchlight, that is the xenon arc, the mechanical start mechanicsm and the searchlight reflector within the vacuum type plasma arc container. A better approach might be the further miniaturizing of the active portion of the xenon lamp, the arc, and separating the reflector and other components external to the xenon arc enclosure.

2.0 FORWARD

This final report covers the work done during the period of 1 October 1976 to 1 October 1979 on Contract No. DAAK70-76-C-0261 for the U. S. Army Mobility Equipment and Development Command, Fort Belvoir, VA 22060. The object of this program was to develop a sealed beam xenon arc lamp with low voltage ignition mechanism in accordance with purchase description for Sealed Beam Xenon Arc Lamp, dated 01 July 1976, marked Attachment 1.

The low voltage start, sealed beam xenon arc lamps developed during this program were manufactured at the ITT Electron Tube Division in Easton, Pennsylvania. Computer aided design techniques for reflector optimization was performed using computer facilities at Lehigh University, Bethlehem, Pennsylvania.

3.0 PURPOSE

The purpose of this program was the development of a metal-ceramic, sealed beam xenon short arc lamp incorporating a low voltage ignition mechanism in accordance with specifications contained in section F, "Purchase Description," Attachment 1, dated 01 July 1976 of Contract No. DAAK70-76-C-0261. Also included in the scope of the contract was the fabrication, test and delivery of three each lamps.

Sealed beam xenon lamp technology at ITT is a marriage of the conventional xenon lamp technology and metal ceramic tube technology which exist at ITT Electron Tube Division in Easton.

The sealed beam xenon lamp is a pressurized optical device consisting of a pair of electrodes, an optical window, a reflector, and a metal-ceramic body. The cathode electrode is made of thoriated tungsten and the anode is fabricated from pure tungsten bar. The lamp has an integral reflector, the position of which is optimized for maximum light output through the sapphire window. The lamps built during this contract require a low voltage mechanism for ignition.

Conventional xenon lamps are normally started by applying a high frequency, high voltage electric pulse between the lamp electrodes, which ionizes the gap gas, thus permitting a low DC voltage to support a continuous arc. The problem with this system is the necessity of providing a high voltage, high frequency power supply which is bulky and represents a reliability problem for the military system. Sealed beam xenon lamps had previously been built which incorporated a metal probe or stinger which can be activated magnetically to momentarily short the two electrodes, thus permitting the DC voltage to ignite and draw an arc as the probe is withdrawn from cathode contact to its rest position, coaxially located within the anode structure.

ITT had previously built sealed beam xenon lamps which required the conventional high voltage, high frequency start. This contact called for ITT to modify its conventional type of sealed beam lamp and incorporate the stinger type of low voltage ignition mechanism.

4.0 LAMP DESIGN

4.1 Overall Design

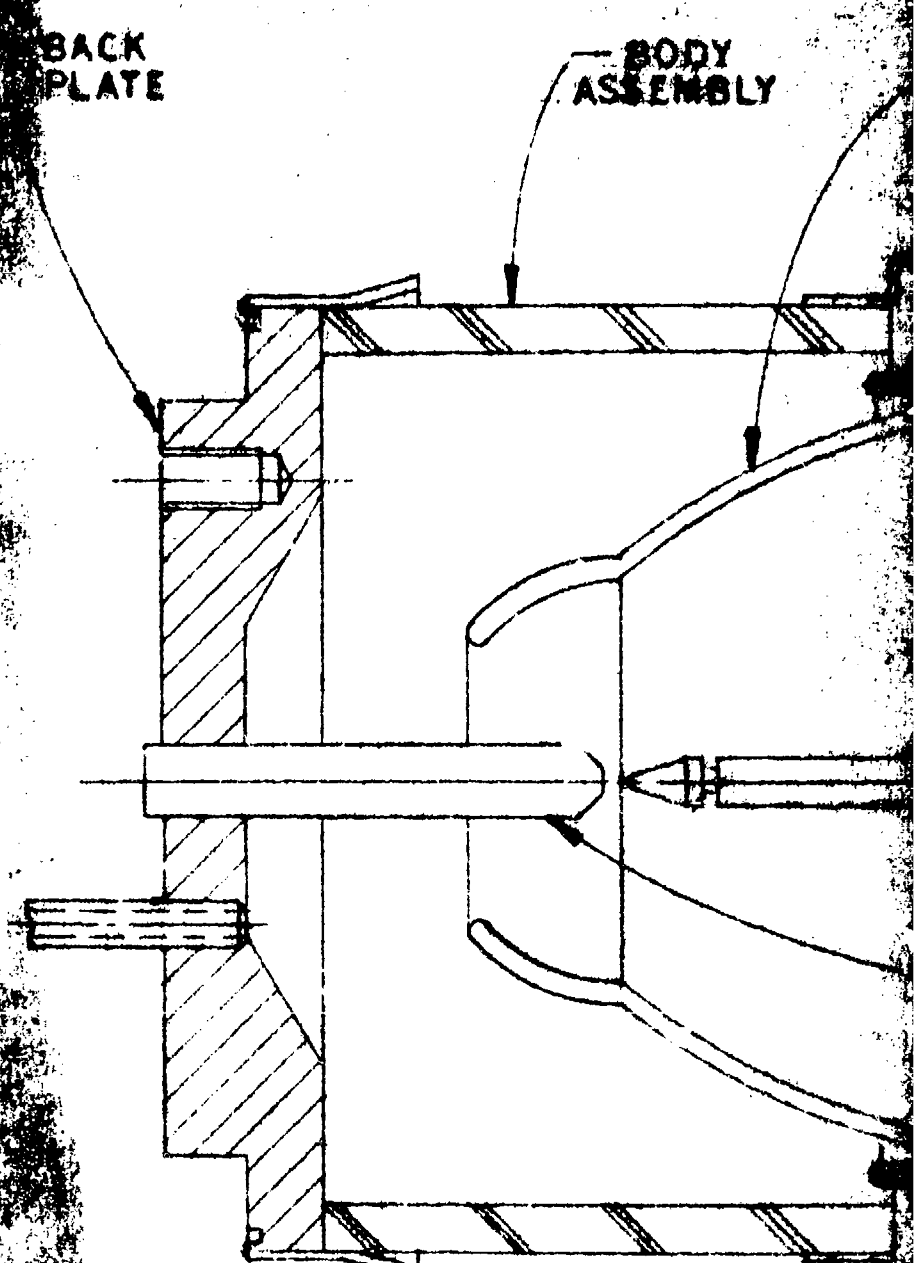
The base point for the design of the low voltage sealed beam xenon arc lamp was ITT's existing high voltage start sealed beam xenon lamp type 994 shown in Figure 1. The initial design called for modification of type 994 to incorporate the low voltage starting mechanism.

A mechanical layout of the ITT Type 994 Sealed Beam Xenon Lamp is shown as Figure 1. The entire assembly is metal-ceramic construction. Sub-assemblies are high temperature brazed or welded, and final assemblies are heliarced. The metal ceramic design is resistant to shock and vibration since it features unitized construction and rugged materials. The lamp is of the two electrode type with the electrode axis parallel to the axis of light projection.

The design can be separated into major sub-assemblies, namely, the window assembly, body assembly, electrode assemblies, and reflector. The narrative to follow describes each in detail. Figure 2 shows all major sub-assemblies for type 994 lamp in the order of assembly into the metal-ceramic body.

The major sub-assemblies are jigged for position and alignment, then heliarc welded together.

Figure 3 shows a completed lamp. The addition of the cooling fins enable the lamp to be conduction/convection or forced convection cooled (see Figure 4).



ISS	E.C.O. NO.	CHGD. BY & DATE
A	ORIGINAL ISSUE	REVISIONS

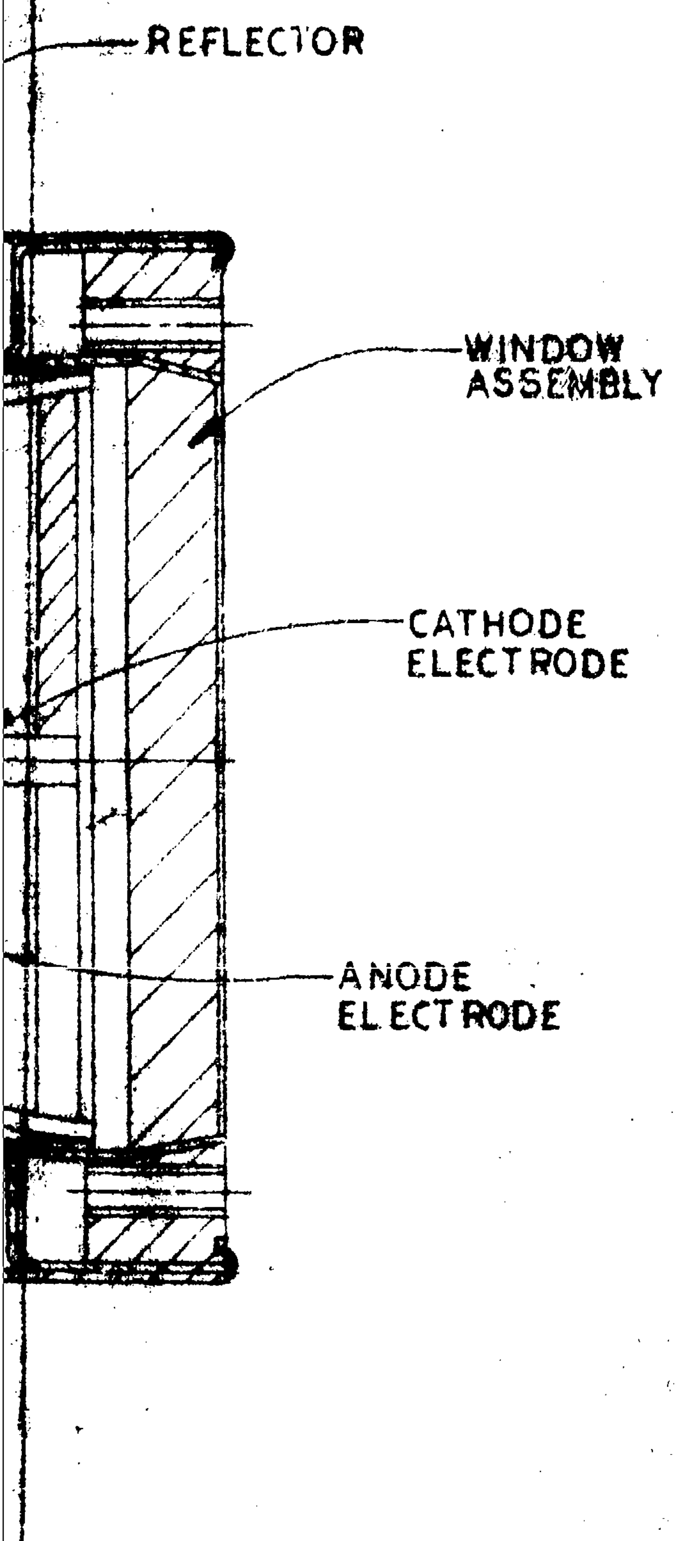

REFLECTOR
WINDOW ASSEMBLY
CATHODE ELECTRODE
ANODE ELECTRODE

FIGURE 2.

EXPLODED VIEW ITT-ETD

SEALED BEAM XENON LAMP

ITT TYPE 0994

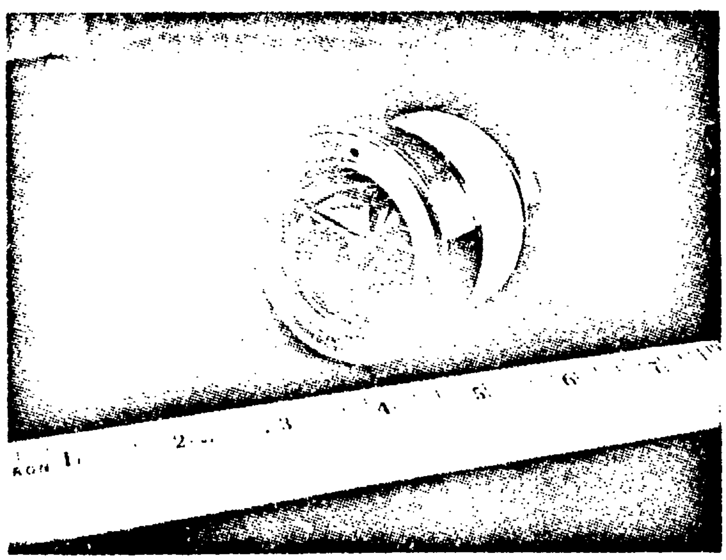


FIGURE 3.

ITT SEALED BEAM XENON LAMP TYPE 0994

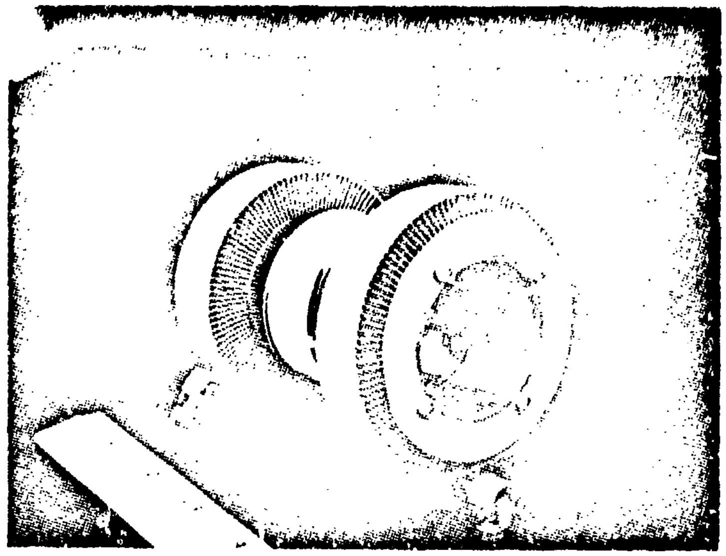


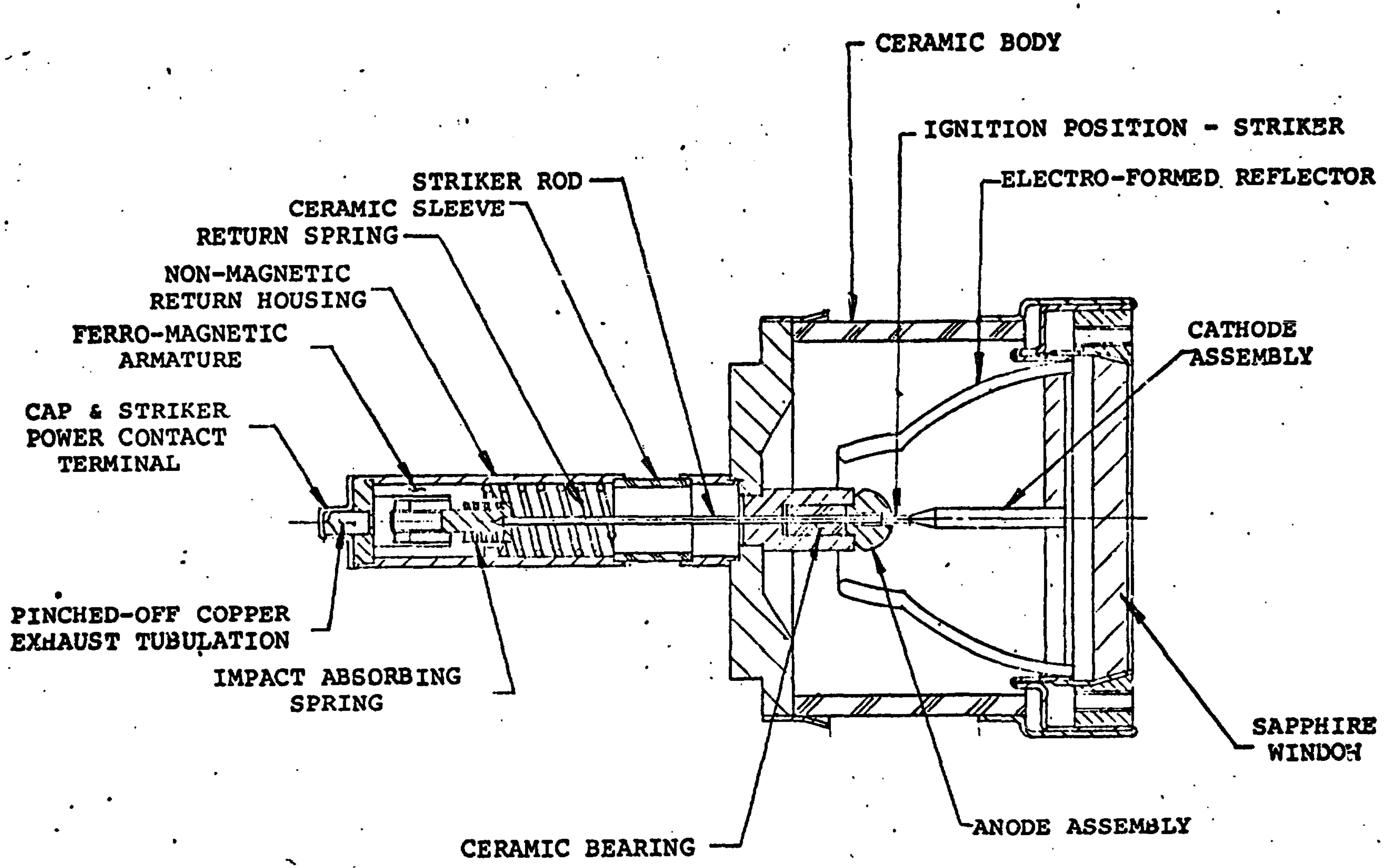
FIGURE 4.

ITT SEALED BEAM XENON LAMP WITH COOLING FINS

The initial redesign of type 994 to incorporate the low voltage start mechanism is shown in Figure 5. This redesign involved replacing the entire rear section of the lamp which previously consisted of a backplate supporting the anode electrode. In this design (Figure 5) the backplate supports the anode in the internal portion of the lamp and solenoid mechanism for inserting and extracting the starting probe on the external side of the plate. The vacuum integrity of the lamp is maintained by a metal bellows. Figure 5 shows the concept of the starting mechanism; the actual starting mechanism used in the initial design is shown in Figure 6. Figures 7 and 8 show exploded views of the initial parts and completed lamp.

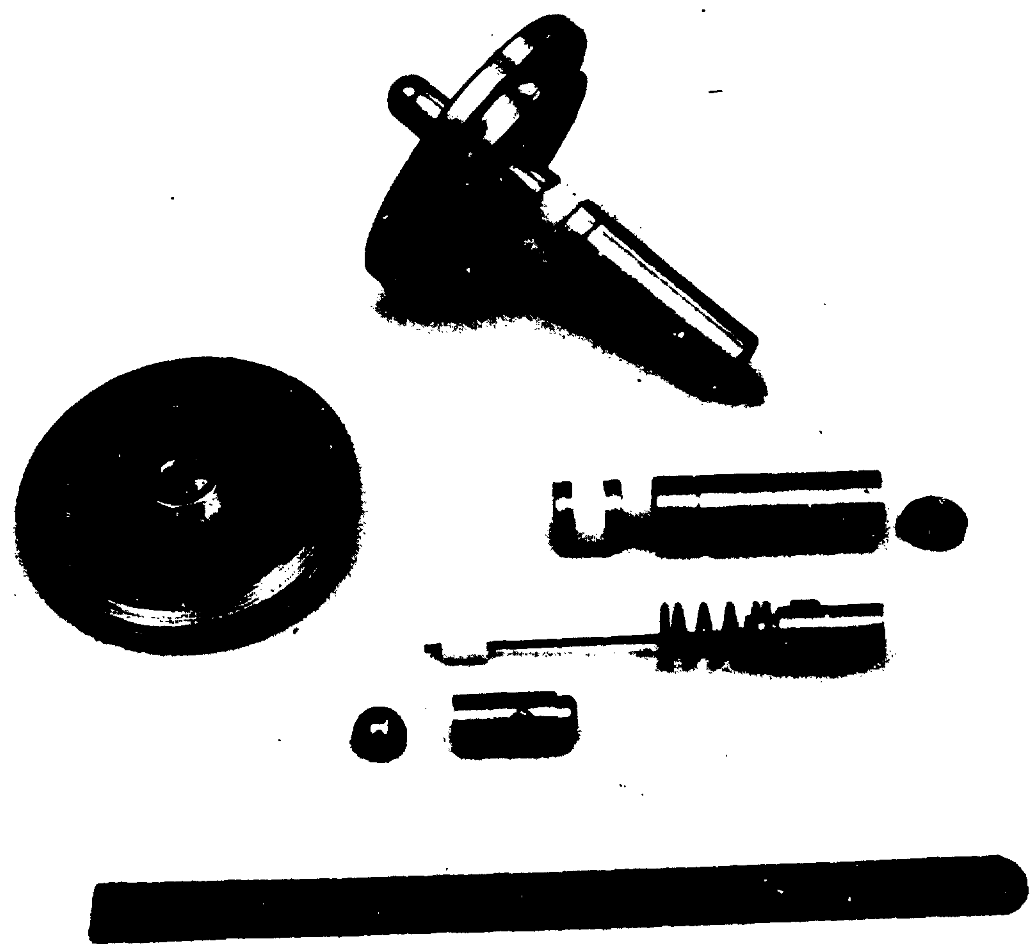
4.2 Low Voltage Ignition Mechanism

The initial design of the low voltage ignition mechanism can best be described by referring to Figures 5 and 6. Basically, the low voltage mechanism involves the use of a striker rod which is controlled by a magnetic field and moves coaxially within the lamp anode. The solenoid activates the striker rod, penetrates the lamp gap, strikes the tip of the cathode and is then rapidly withdrawn. A low voltage is applied between the cathode and striker coincidently with the movement of the striker back into the anode, thus drawing an arc between the cathode and anode. This arc will be sufficient to ionize the gas and initiate a sustained arc when transferred from the striker to the anode tip as the striker returns within the body of the anode. On the external side of the rear plate, a ceramic sleeve electrically isolates the backplate of the lamp, which is at



ITT DEVELOPMENT MODEL, 1.0 KW SEALED BEAM LAMP
WITH LOW VOLTAGE IGNITION MECHANISM

FIGURE 5.

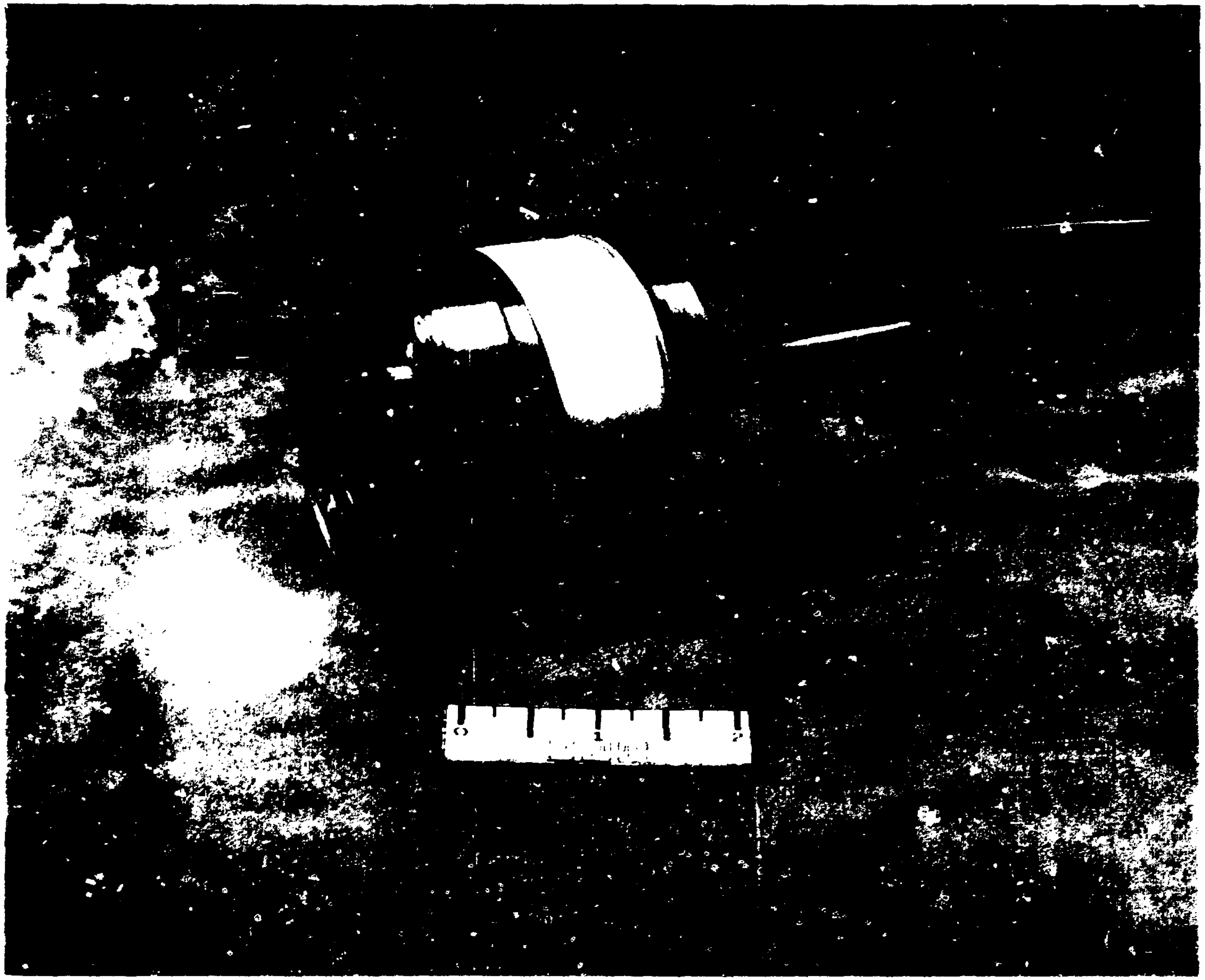


LOW VOLTAGE XENON LAMP STARTING MECHANISM

FIGURE 6.

EXPLODED VIEW - ITT LOW VOLTAGE START XENON LAMP

FIGURE 7.



ITT LOW VOLTAGE START XENON LAMP

FIGURE 8.

an anode potential from the starting actuator housing and associated ignition circuitry. The anode voltage is applied to the backplate of the lamp and the cathode connection is made to the metal structure surrounding the window which supports the reflector, the cathode and cathode heat sink fin structure. Internal to the anode is a ceramic member which provides a bearing surface for the striker rod. The ceramic bearing insures coaxial alignment between the striker rod and the tip of the cathode.

Figure 5 shows the lamp in a non-operational condition with the striker withdrawn within the anode assembly. In the equipment there is a coil surrounding the return housing sleeve. The initial step in activating the lamp is to provide voltage to this coil resulting in a magnetic field which drives the ferromagnetic armature forward, thus injecting the striker rod into the gap between the anode and the cathode. The striker rod moves forward until it contacts the cathode. At this point the voltage is removed from the magnetic coil and simultaneously, the DC voltage is applied between the striker rod and the cathode. The return spring now withdraws the striker rod from the anode-cathode gap back into the anode assembly. As the striker rod is moving away from the cathode the DC voltage which has been applied results in an arc between the cathode and the striker rod. The arc is then transferred from the striker rod head to the anode as the striker rod withdraws within the anode. Just forward of the ferromagnetic armature and incorporated in the armature is an impact absorbing spring. The purpose of this spring is to absorb any sudden shock which might result from the striker rod making contact with the cathode.

Figure 7 shows an exploded view of the lamp with the backplate and striker rod in the upper right hand portion. Figure 8 shows the assembled lamp with the striker housing to the right.

4.2.1 Electrodes

The material for the electrodes of the sealed beam lamp are similar to a conventional compact xenon lamp. The cathode is machined from 2% thoriated tungsten and the anode is manufactured from pure tungsten.

Both electrodes are aligned along the axis of light projection of the lamp.

The cathode is supported within the reflector by three (3) supporting struts. These struts are brazed to the cathode circumference to allow for expansion during operation.

The anode is brazed directly into the backplate of the lamp for thermal and mechanical integrity considerations. The thermal path from the anode tip is through the backplate to the cooling fins. Figure 4 shows a complete lamp with front and rear cooling fins. It may be noted that these fins are removable and as such could form a part of the mating searchlight structure.

4.3 Reflector Design

Test data on ITT's high voltage start lamp type 944 demonstrated a non-uniform beam intensity pattern at the center of the illumination image. The specification for the type 999 lamp to be developed under this contract would not permit this variation in illumination. It was necessary, therefore, to redesign the reflector.

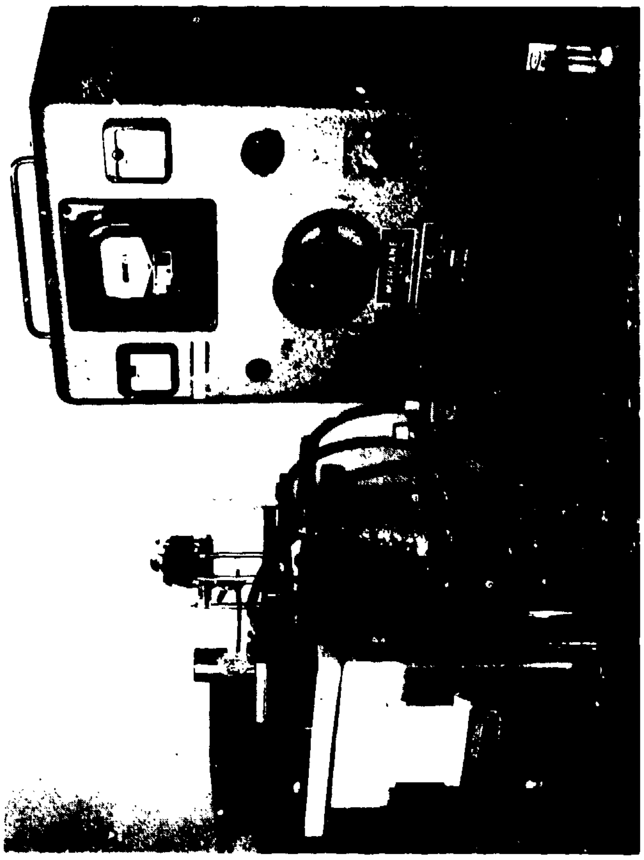
The reflector was redesigned using conventional design techniques. The design was based on the use of a classical ellipsoid. Figure 9 shows various operations involved in the design and fabrication of the reflector.

The mandrel required for electroforming the reflector was generated by the use of a numerical controlled lathe, shown in Figure 9. The reflector consists of a nickel substrate and a silver plated reflecting surface. ITT developed the techniques required to fabricate the reflectors. After the design of the reflector had been finalized, ITT investigated the use of outside vendors to reduce production costs. ITT fabricated and provided mandrels to outside vendors. Both the ITT fabricated reflectors and the vendor fabricated reflectors proved satisfactory (Figure 10).

The final design of the reflector was unchanged from the initial design lamps.

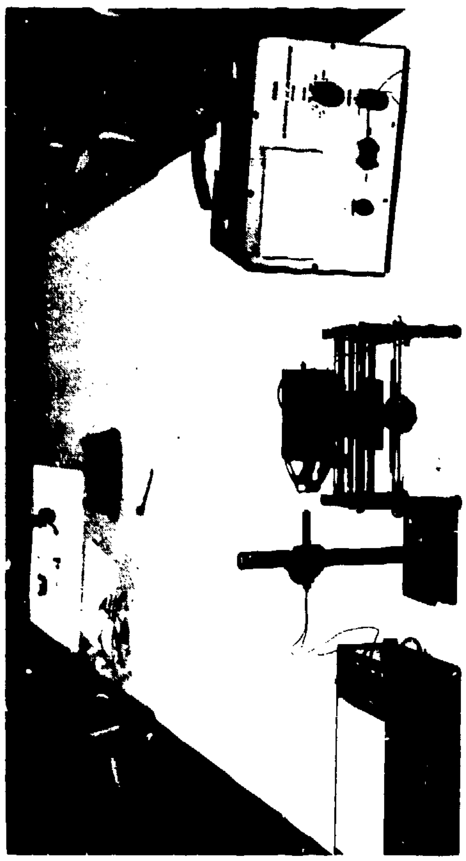
4.4 Window Assembly

The window assembly used in the design of the low voltage lamp type 999 was essentially the same as the window assembly for type 994. ITT purchased the metalized window/flange assembly completely brazed from an outside vendor. The window assembly as shown in Figure 11 consisted of the window support, on the left, which included four tapped holes for mounting the heat sink and the

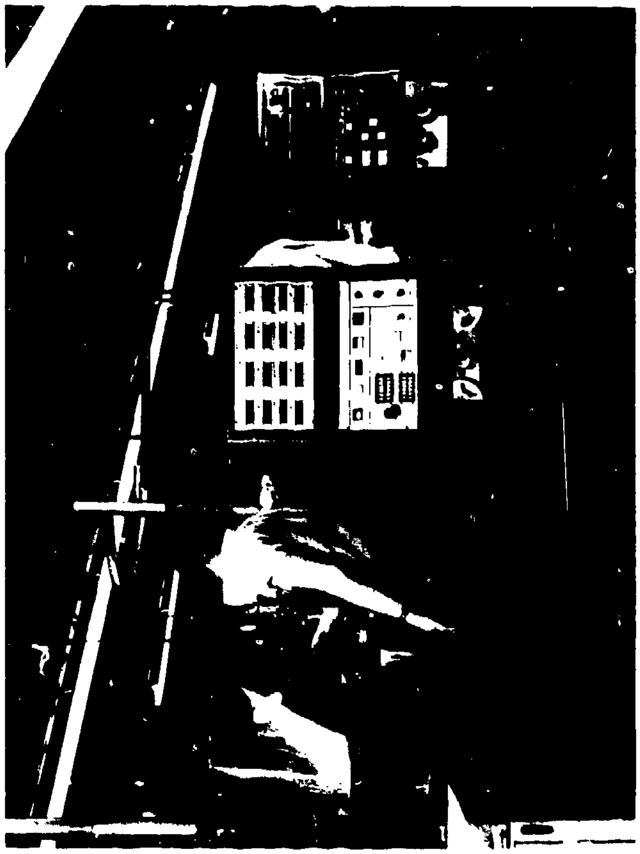


PROTOTYPE REFLECTOR FABRICATION SET-UP

ITT-ETD PRODUCTION REFLECTOR FABRICATOR FACILITIES



SEALED BEAM REFLECTOR TEST EQUIPMENT



ITT-ETD NUMERICALLY CONTROLLED LATHES

FIGURE 9.

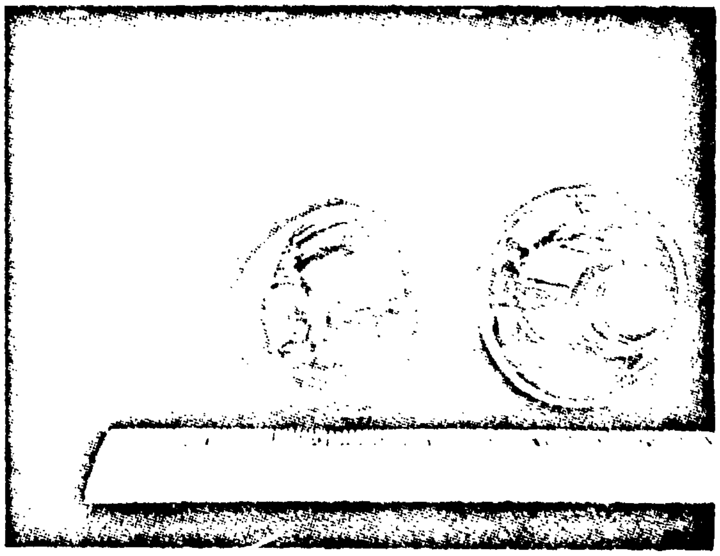


FIGURE 10.

SEALED BEAM LAMP REFLECTORS

The reflector on the left side was manufactured by ITT-ETD.

The reflector on the right side was purchased by ITT-ETD for this program.

FIGURE 11.

PURCHASED SEALED BEAM XENON LAMP WINDOW

AND

WINDOW SUPPORT HARDWARE

cathode connection; the window heliarc flange, shown at the right, was used to mount the window assembly into the body of the lamp; and the sapphire window proper, brazed into a kovar flange (shown in the center of the assembly). The window flange was heliarc welded into the window heliarc flange.

During the course of the development program, the sapphire window was reduced in thickness to enhance light transmission and reduce cost.

4.5 Body Assembly

The main structural supporting member for the sealed beam lamp is the body assembly. This metal-ceramic assembly serves to align and space the cathode and anode and is the wall of the pressure container for the xenon gas.

The ITT body consists of a kovar rear ring, a moly-maganese metalized ceramic body, and a front kovar ring. The window-cathode assembly is welded concentrically to the front ring while the anode assembly is welded mutually concentrically to the rear ring. The ceramic insulating body has been glazed on the outer surface to prevent dirt and contamination buildup. The finalized body ceramic length was reduced by a factor of three from the original prototype 994 device as a consequence of the elimination of the prior 35 KV high voltage isolation requirment and size effectiveness.

4.6 Final Design

The final design of the low voltage start lamp type 999 is in essence, the same as the initial design described. Figures 12, 13 and 14 show various exploded views of the final lamp design. The major change involved a redesign of the backplate of the lamp to provide a reentrant anode support.

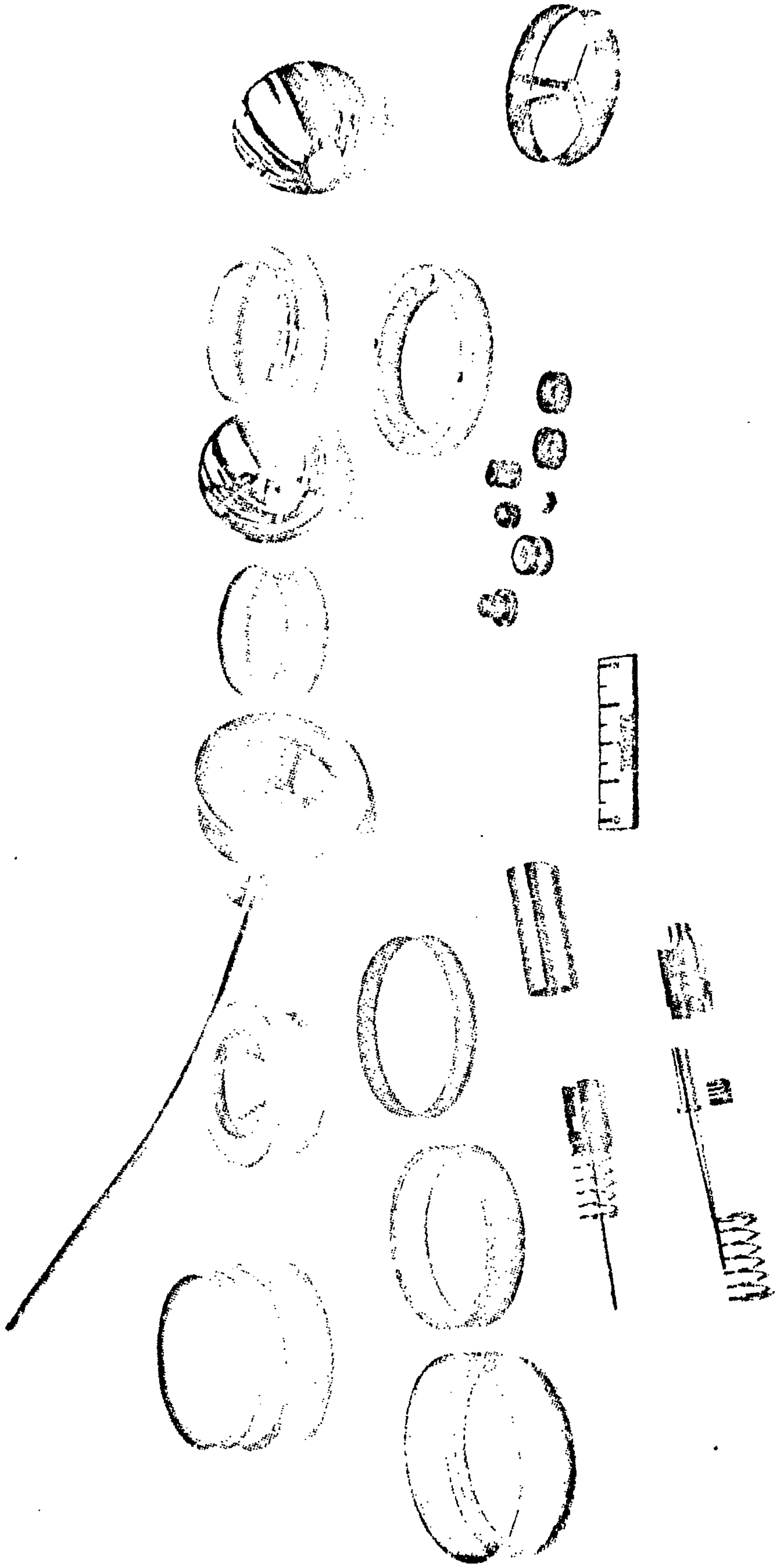


FIGURE 12.
Parts used in Final
Design Lamp

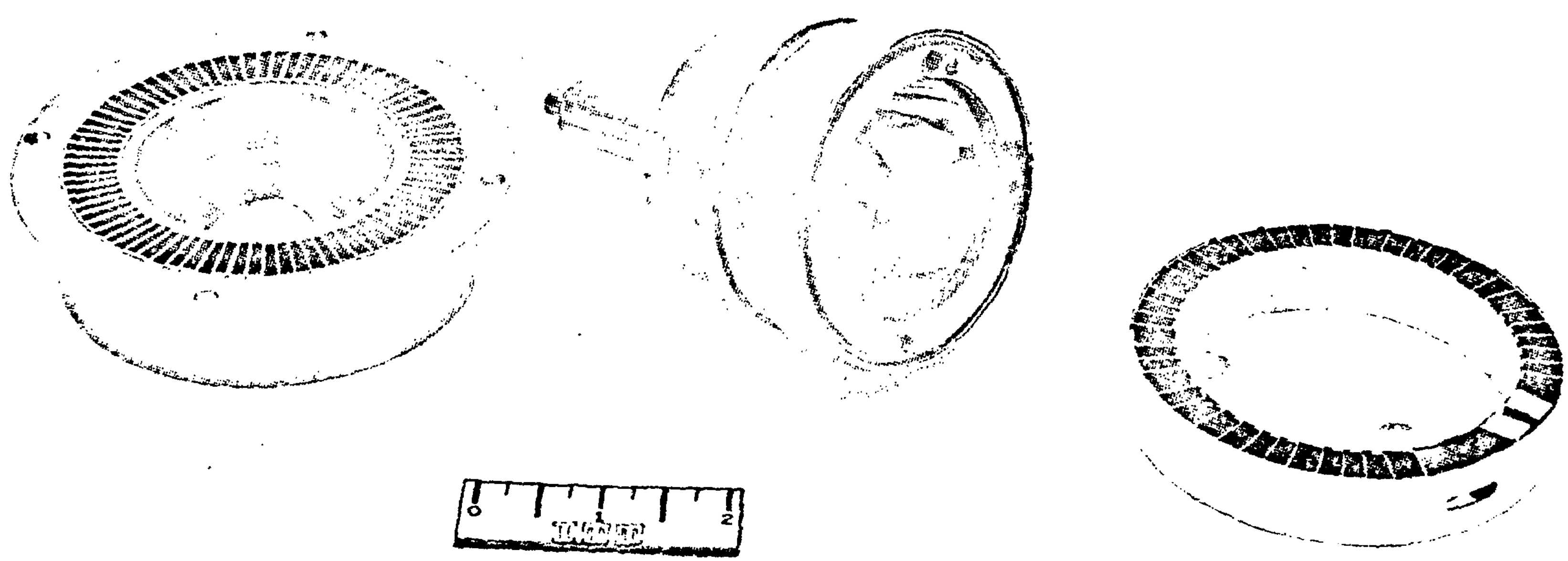


FIGURE 3.

Lamp Type 999
and Cooling Fins

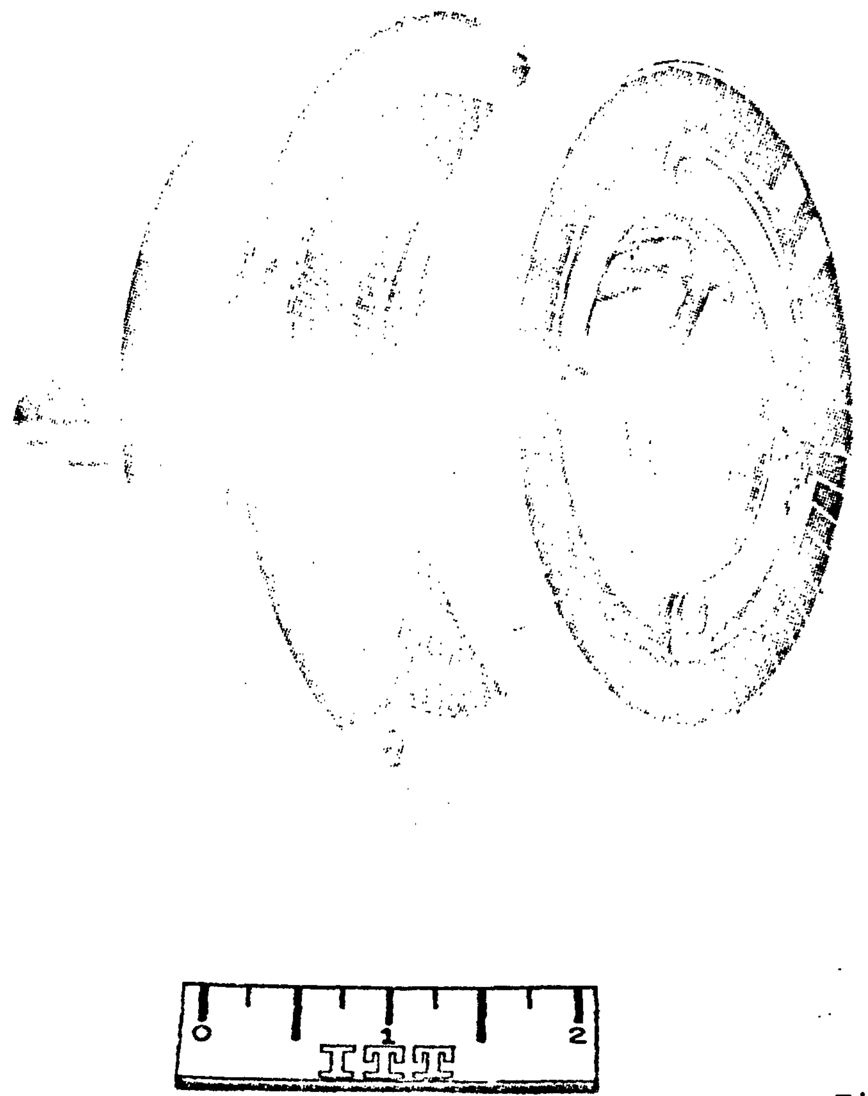


FIGURE 14.

Final Design Low Voltage
Start Sealed Beam Xenon Lamp

5.0 MAJOR PROBLEMS ENCOUNTERED

During the course of the development, two major problems were encountered. The first involves the welding of the striker rod to the cathode during lamp ignition and the second involved the reliability of a ceramic metalized joint under the severe pressure and thermal conditions. A brief discussion of the problems follows.

5.1 Striker Rod Welding Problem

The initial design phase of the program progressed rapidly and the first lamp was built. The lamp processed normally and no problems were encountered until initial test. The initial start of the first lamp went satisfactorily. The lamp fired and appeared to produce sufficient light output. Initial data on lamp voltage and current was recorded and the lamp was turned off. Upon attempting to restart the lamp, the lamp failed to ignite. Repeated attempts to start the lamp failed. The lamp was removed from the test housing and it was observed that the striker had welded to the cathode, thus short circuiting the electrodes. External mechanical shear force was exerted and the weld was broken. Repeated attempts to restart the lamp repeatedly resulted in the striker-cathode welding.

Various analyses were conducted and design modifications made in an attempt to solve the striker welding problem. All of these design modifications failed and lamps continued to fail due to striker welding.

The concept of the low voltage start using the retractable striker had previously been proven successful by Night Vision

Laboratories and the associated electronic circuitry required had been developed. The Night Vision Laboratories had furnished ITT the electronic circuitry required to start the lamps as Government Furnished Equipment. After numerous failures, it was decided to investigate the starting circuitry. It was then discovered that the circuitry, which was designed to provide repeated actuation of the striker rod until lamp ignition and then prevent reoccurring strikes after the lamp ignited, was malfunctioning. What was actually occurring was that the striker would perform satisfactorily and ignite the lamp, however, the circuitry would continue to activate the striker which caused the striker to contact the cathode while full lamp current was flowing, thus welding the striker to the cathode. ITT modified the GFE so that a single push button would provide only a single stroke of the striker rod. This solved the problem and all future lamps started satisfactorily.

Another failure occurred involving the electrical short circuiting ballast resistor in the electronic mechanism. This failure occurred during a Life Test and resulted in electrode melt down in the lamp and catastrophic failure.

These failures of the electronic circuitry associated with the low voltage start indicate that additional development work may be necessary in this interface area to insure reasonable field reliability.

The design task of resolution of the striker welding problem, was compounded by the ITT Electron Tube Division suffering from a three month strike which resulted in approximately a ten month delay in program progress and depleted most of the program funds. ITT completed the program on ITT funds.

5.2 <u>Metalizing Reliability Problem</u>

After the initial problem of welding of the striker rod was resolved, the program continued with the fabrication and testing of lamps. The major problem with testing involved the reliability of the ceramic-to-metal seals at the rear (anode interface) of the lamp. The metalized seal at the rear of the lamp would fail resulting in a leak which caused catastrophic failure. ITT was procuring a metalized ceramic from an outside vendor. The quality of the metalizing was questioned and a second vendor was introduced. An analysis of the metalizing indicated that the quality was such that it would be considered satisfactory for high power tube ceramic-metal seal applications. After a number of tests, it was concluded that this particular seal, due to the high power density of the lamps and the high pressure of the xenon within the lamp, was under unusually high mechanical and thermal stress. It was further concluded that a higher quality of metalizing was required to provide reliable operation.

No other major problems were encountered during the fabrication and testing of the lamps.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Price

ITT originally estimated that a lamp of the type developed on this program could be sold for about three times the price of a conventional xenon lamp. ITT now feels that this lamp will probably cost in excess of $1,000 (1978 dollars) in the production quantities normally associated with military searchlights. The reason for the upward revision of the price estimates involves the greater than anticipated costs of the sapphire window assemblies and the extraordinary precision required in the assembly of the magnetic starting mechanism and cathode/reflector assemblies.

6.2 Reliability

Many of the lamps fabricated (of both the low voltage and high voltage start types) perform satisfactorily for many hundreds of hours. However, a greater than anticipated number of catastrophic failures occurred with both types, one lamp exploded at ITT life test. The reliability problem appears to be the result of high power density and starter mechanism-control circuit interface problems. One of the prime features of the sealed beam lamp is that it incorporates within one vacuum tight envelope all of the active elements of the lamp including the reflector. This results in substantial miniaturization over the conventional type xenon lamp searchlight which separates the lamp and its plasma discharge from the reflector. While achieving miniaturization, the sealed beam lamp does result in a very high power density package. This high power density tends to produce overheating and increased gas pressure on all seals. Still another problem with this design concept is the fact that the reflector is in close proximity and within the same vacuum envelope as the lamp electrodes. These lamp electrodes during operation of the lamp, especially the cathode, tend to vaporize tungsten which was observed to coat the surface of the reflector, thus rapidly reducing the reflector efficiency.

A second problem involves the moving striker mechanism and its interface with the electronic control circuitry. This problem of reliability is described previously in this report and resulted in serious problems during this development program.

6.3 Manufacturing Methods Program

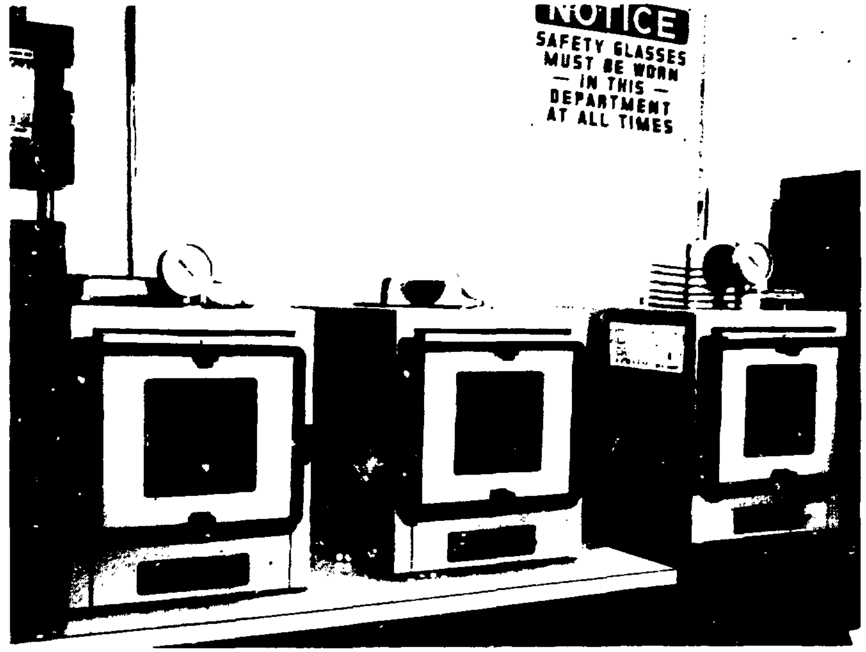
ITT would recommend a Manufacturing Methods Program aimed at improving the reliability and reducing the cost of the lamp. A major thrust of the reliability improvement program would be the redesign of the lamp seals to reduce mechanical and thermal stress. A second major thrust would be evaluating the reliability of the electronic control and striker mechanism package.

The Manufacturing Methods Program should also address the areas of window and reflector fabrication and test methods to reduce costs.

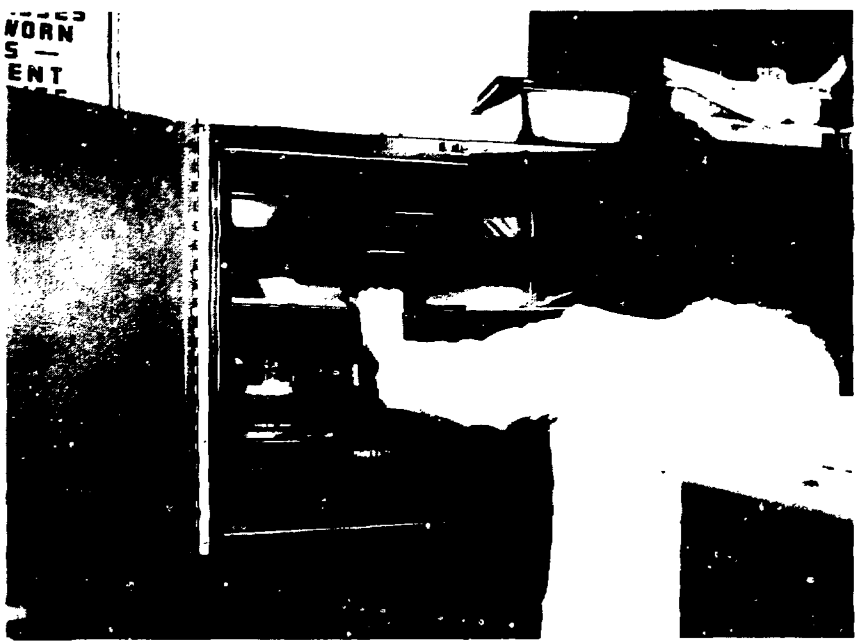
7.0 ITT MANUFACTURING FACILITIES

The following photographs depict the ITT facilities utilized during the development, design, fabrication, process and test phases of this sealed beam lamp program.

HYDROGEN FURNACE FOR XENON LAMPS

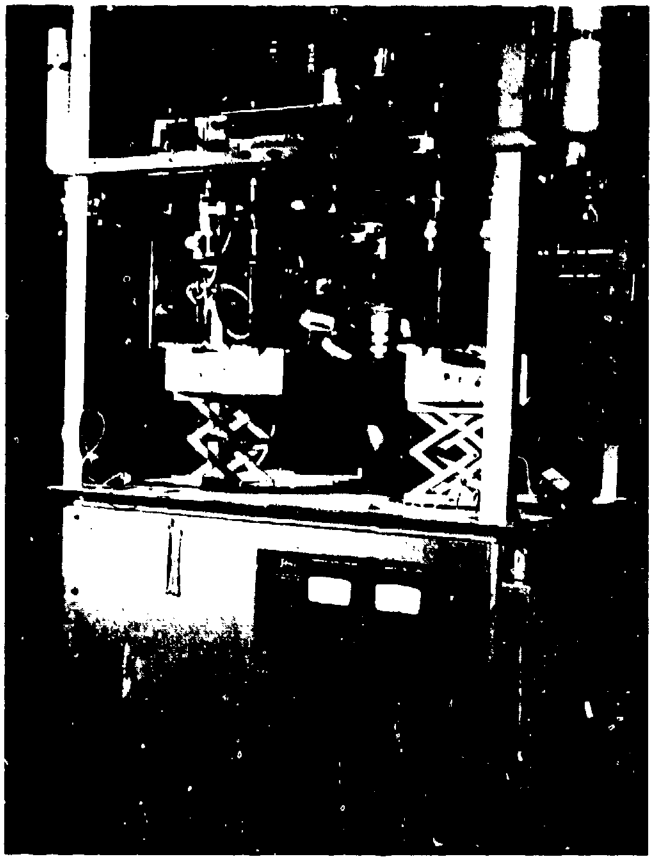


TEMPERATURE CONTROLLED VACUUM STORAGE CHAMBER
FOR XENON LAMP PARTS STORAGE



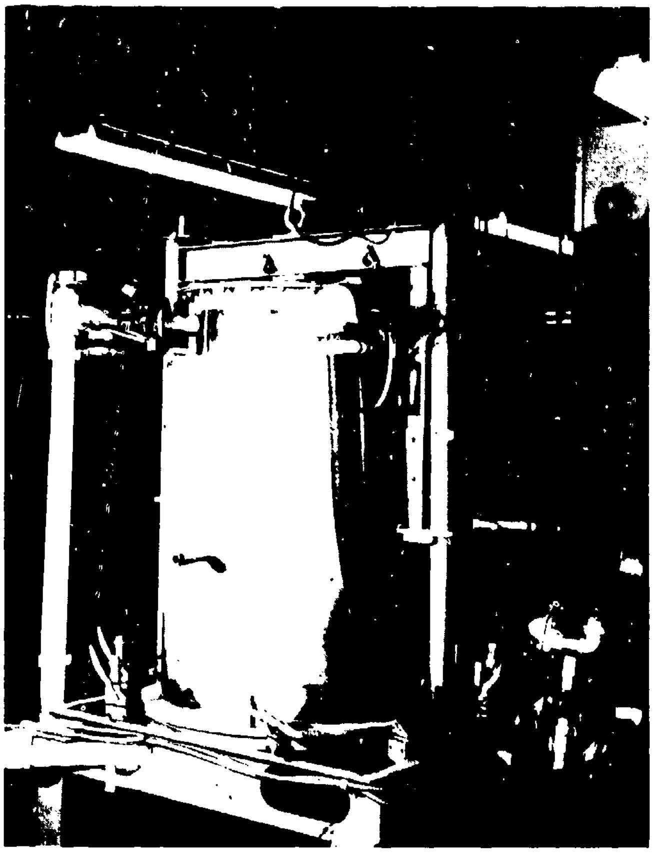
TEMPERATURE CONTROLLED CABINET FOR QUARTZ PARTS

XENON LAMP SUB ASSEMBLY STORAGE FACILITIES

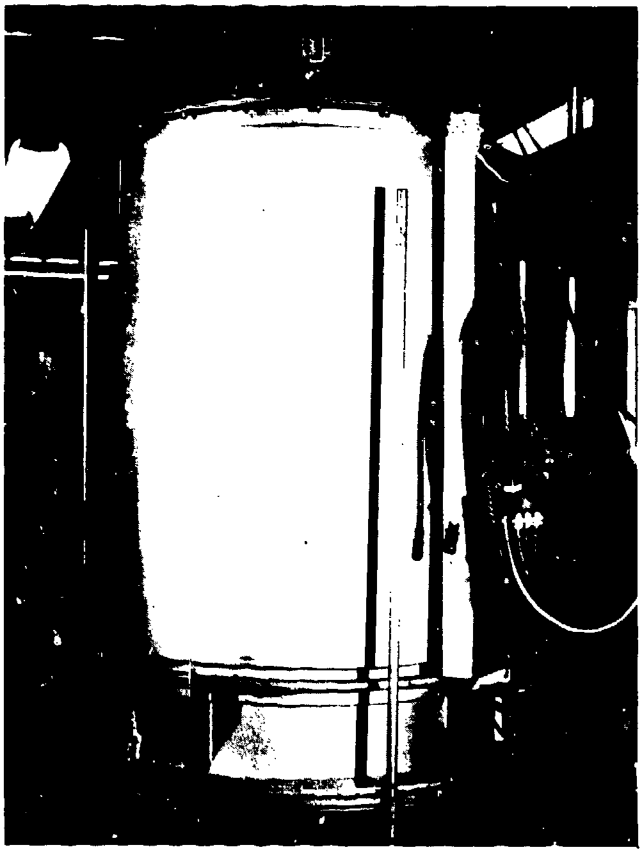


XENON LAMP PRODUCTION EXHAUST STATION

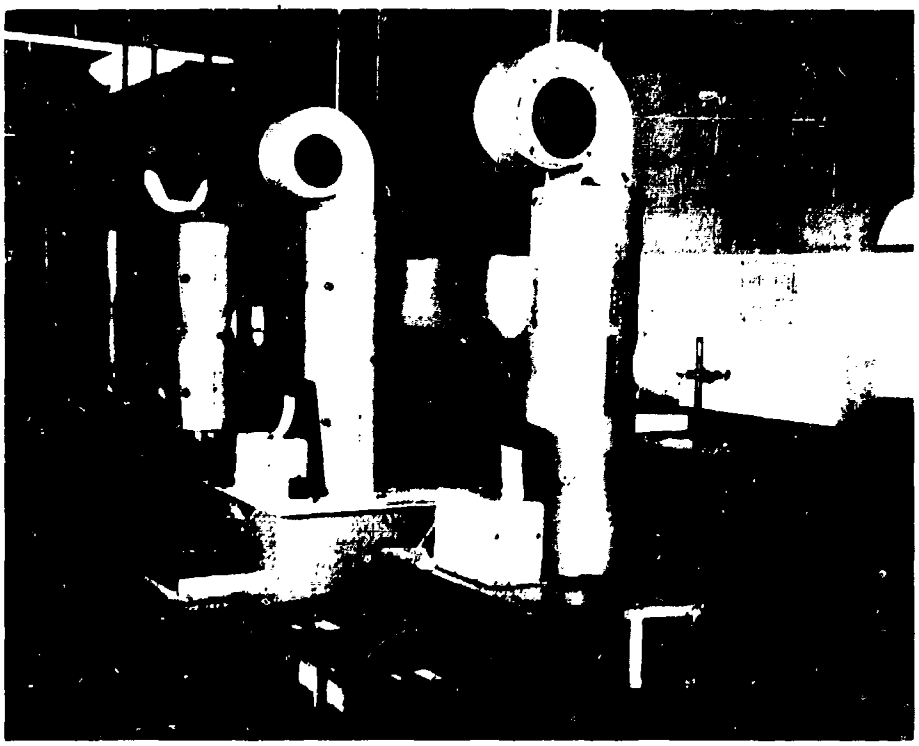
PRODUCTION EXHAUST FACILITIES



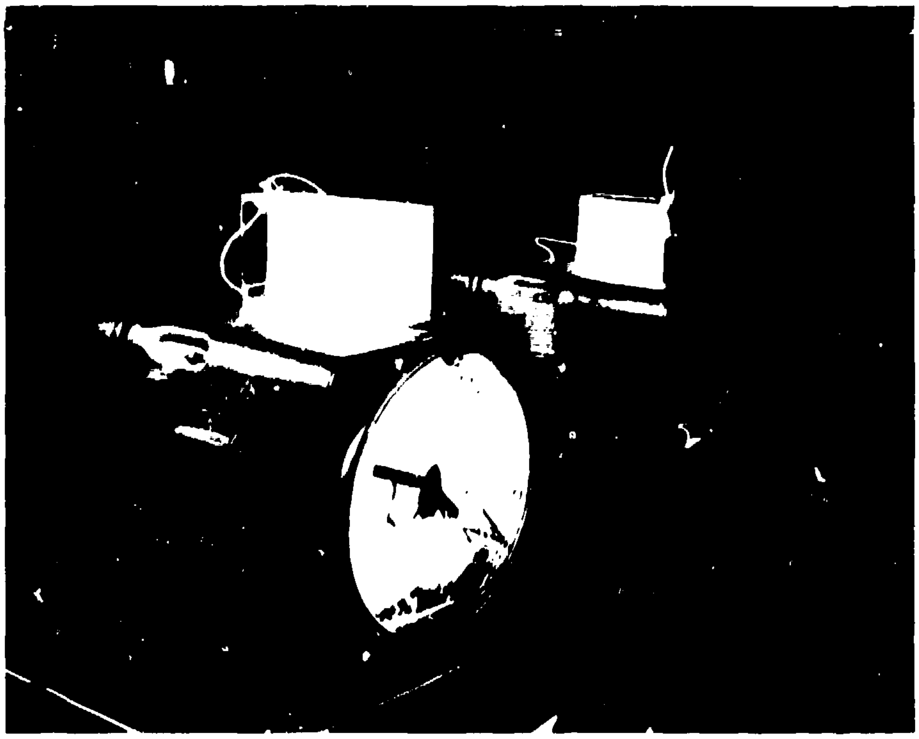
CERAMIC METALIZING FURNACE



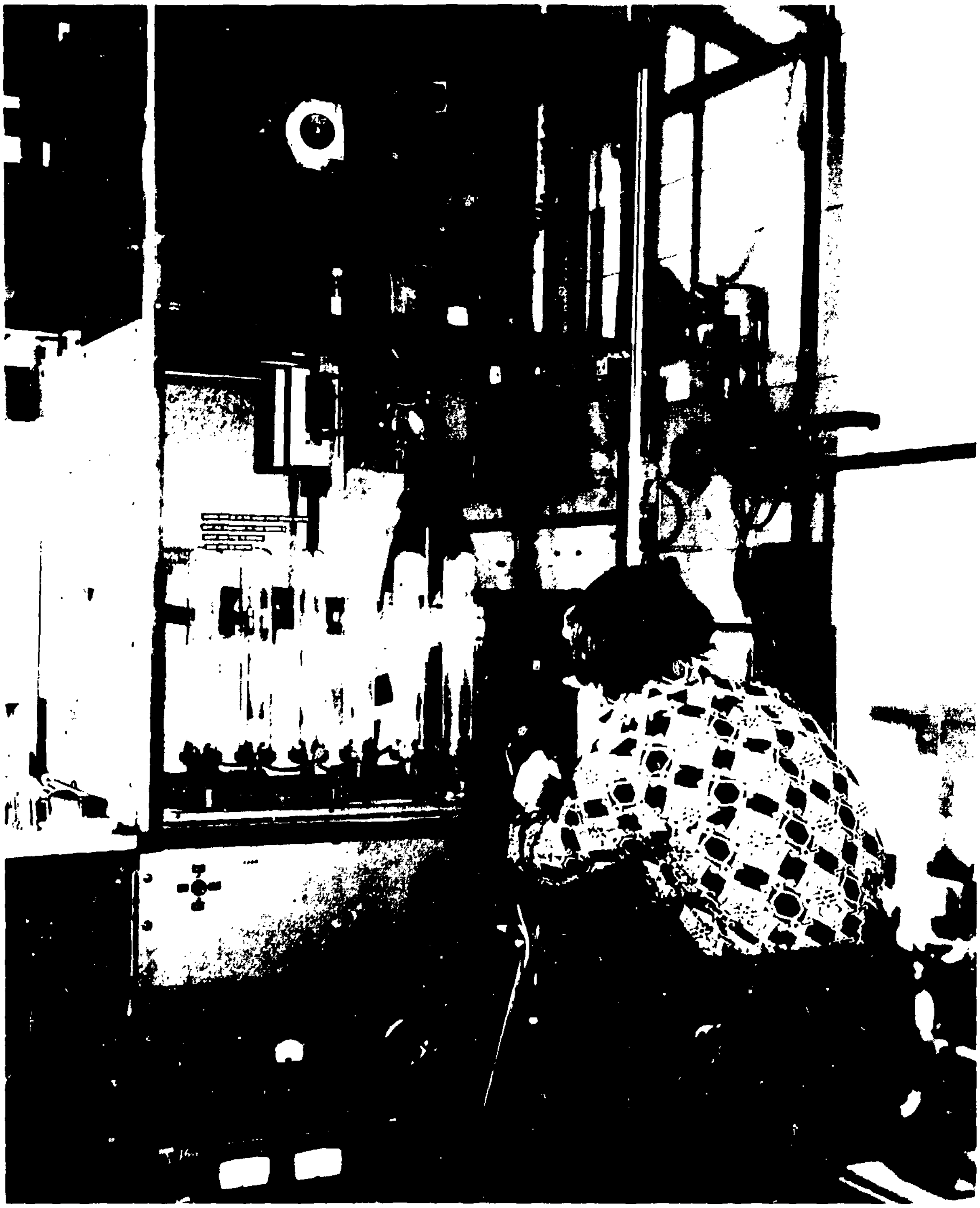
HYDROGEN BRAZING FURNACE



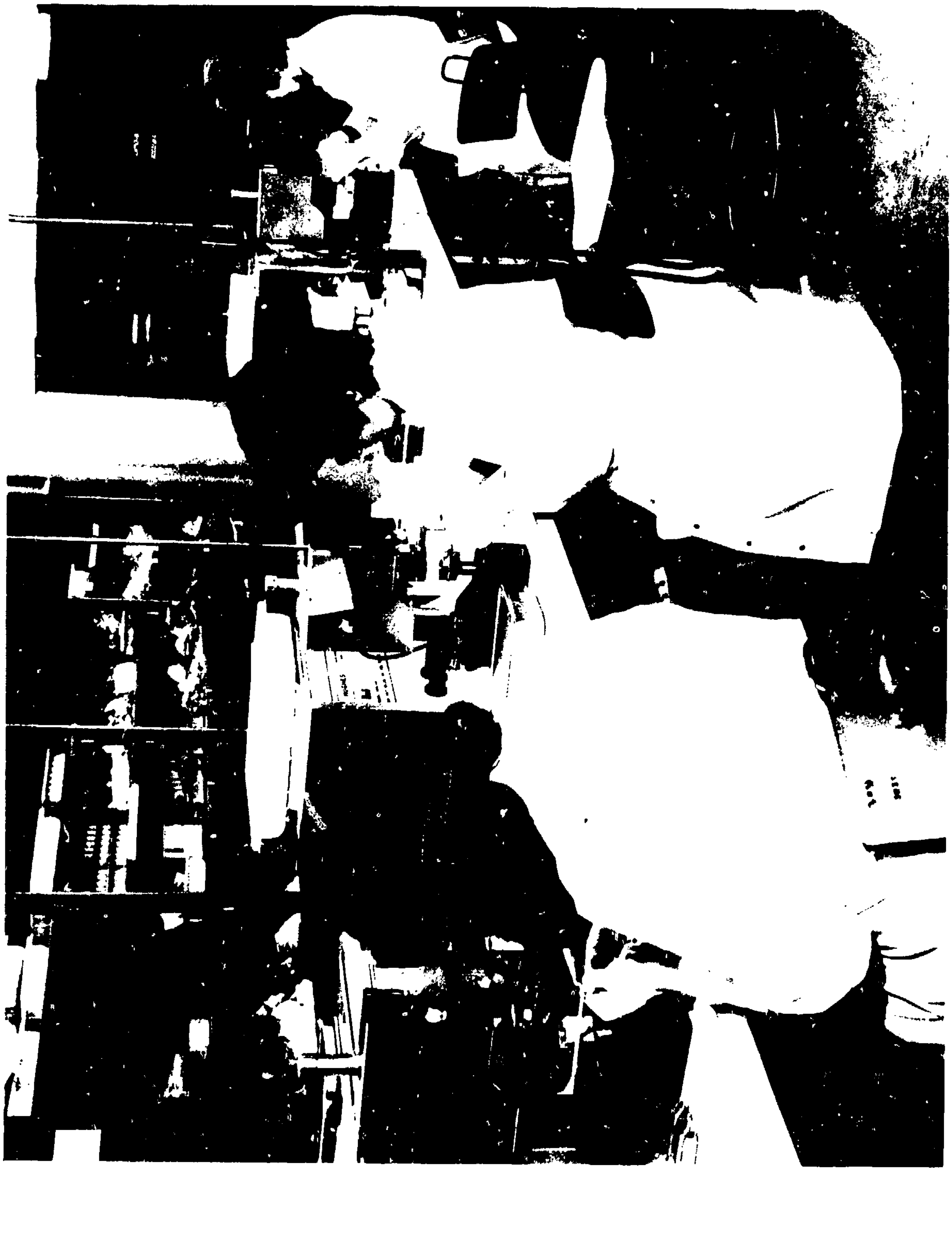
ITT-ETD XENON LAMP TEST FACILITIES



I.O. KILOWATT PRODUCTION XENON LAMPS ON LIFE TEST



XENON LAMP ELECTRODE HIGH TEMPERATURE PROCESSING EQUIPMENT



ITT XENON LAMP ASSEMBLY FACILITY